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Alterations of oral functions and dental malocclusions in adolescents: a cross-sectional population-based study

Alterações das funções orais e má oclusão em adolescentes: um estudo transversal de base populacional

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Abstract *This article aims to assess whether alterations of oral functions (AOF) are associated with malocclusion (MO)'s type and severity. Cross-sectional study of a representative sample of 332 adolescents aged 12 years in São Luís-MA, Northeastern Brazil. MO criteria included Angle's classification, Dental Aesthetic Index, and other morphological problems. The AOF were evaluated by breathing, phonation, chewing, and swallowing. Odds ratios (OR) and 95% confidence intervals (95%CI) were calculated using logistic and multinomial regression analyses (α=5%). Mouth breathing was associated with defined (OR=3.84; 95%CI=1.45-10.12), disabling (OR=4.34; 95%CI=1.99-9.49), and class III (OR=4.15; 95%CI=1.19-14.54) MO. Phonation problems were associated with defined (OR=2.01; 95%CI=1.02-4.39), disabling (OR=3.04; 95%CI=1.55-5.96), and Class II (OR=2.02; 95%CI=1.28-3.18) MO. Chewing disorders were associated with posterior crossbite (PCB) (OR=2.32; 95%CI=1.12-4.82). Swallowing disorders were associated with Class III MO (OR=5.66; 95%CI=1.35-23.71), PCB (OR=6.13; 95%CI=2.76-13.62), and posterior open bite (OR=4.53; 95%CI=1.72-8.92). Breathing and phonation alterations are associated with MO in anterior arch segments, while chewing and swallowing disorders, in the posterior segments.*

Key words *Malocclusion, Mouth Breathing, Phonation, Swallowing*

Resumo *O objetivo deste artigo é avaliar se alterações das funções orais (AFO) estão associadas ao tipo e gravidade da maloclusão (MO). Estudo transversal com amostra representativa de 332 adolescentes de 12 anos em São Luís-MA, Nordeste do Brasil. Critérios de MO incluíram Classificação de Angle, Índice de Estética Dental e outros problemas morfológicos. As AFO foram avaliadas por respiração, fonação, mastigação e deglutição. Odds ratios (OR) e intervalos de confiança de 95% (IC95%) foram calculados em análises de regressão logística e multinomial (α=5%). Respiração oral foi associada com MO definida (OR=3,84; IC95%=1,45-10,12), incapacitante (OR=4,34; IC95%=1,99-9,49) e classe III (OR=4,15; IC95%=1,19-14,54). Problemas de fonação foram associados às MO definidas (OR=2,01; IC95%=1,02-4,39), incapacitantes (OR=3,04; IC95%=1,55-5,96) e Classe II (OR=2,02; IC95%=1,28-3,18). Alterações na mastigação foram associadas à mordida cruzada posterior (MCP) (OR=2,32; IC95%=1,12-4,82). Deglutição atípica foi associada à MO Classe III (OR=5,66; IC95%=1,35-23,71), MCP (OR=6,13; IC95%=2,76-13,62) e mordida aberta posterior (OR=4,53; IC95%=1,72-8,92). Alterações de respiração e fonação estão associadas às MO nos segmentos anteriores do arco, enquanto as de mastigação e deglutição, nos segmentos posteriores.*

Palavras-chave *Má oclusão, Respiração Bucal, Fonação, Deglutição*

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Introduction

Dental malocclusion is a major oral health problem[1,2], given its high magnitude and aesthetic impact[3,4], possibly affecting psychosocial[5] and quality of life[6] aspects. Its prevalence varies globally. While 83.3%[7] is recorded in India, in Brazil, 19.8% of 12-year-olds have very severe or disabling malocclusions, as per data from the latest national oral health survey[1].

Many criteria are available to diagnose malocclusions. DAI was chosen mainly for providing objective measures of different occlusal problems and enabling prioritization of treatment needs[1,2]. Thus, the DAI expresses much more the shape of the anterior region of the dental arch than the orofacial function[8]. Although there are indications that function interferes in the form of biological structures[9-15], the relationship between functional alterations of the stomatognathic system and malocclusions is not yet fully understood. Some studies have suggested an association between changes in breathing[9-11,14], speech adaptations[12,13], and swallowing[13,15] with malocclusions. However, other authors found no association between functional alterations and malocclusions[16-18].

There is no consensus on the association of functional alterations with malocclusions, nor whether they influence malocclusion's type and severity. Studies generally evaluate malocclusion through stringent criteria and extensive age groups[4,15]. Also, they do not account for the sample design[3,13], do not evaluate changes in the chewing function[13,15], nor consider the possibility of confounding bias in statistical analyses[3,13]. This study has a large sample. It considered the study design and confounding biases, and performed chewing evaluations.

Therefore, the study aimed to assess the association between functional alterations of the stomatognathic system and malocclusion. The research hypothesizes that functional alterations can cause muscle imbalance, with repercussions in the modeling/remodeling of craniofacial bones, as well as in teeth position in the dental arches, harming dentofacial harmony and balance, thus associating with high prevalence and severity of malocclusions.

Methods

Study Area and Design

This study followed the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) guidelines[19]. This is a cross-sectional population-based study held in São Luís, Brazil. São Luís is located on an island on the northern coast of the state of Maranhão, Northeastern Brazil. The human development index (HDI) was 0.768 in the last Brazilian census, in 2010, ranking first in Maranhão and 249th in Brazil, and had 1,014,837 inhabitants. At the time, the monthly per capita household income was US$ 434.54, with a Gini index of 0.627 and illiteracy rate of 4.6%[20].

Sampling design

Students aged 12 years of both genders enrolled in public and private elementary schools were the reference population. The sample design was two-stage clustered and stratified by school type (public or private). Schools (primary sampling units) and students (secondary sampling units) were randomly selected. Lists of schools available at the Ministry of Education, Municipal Secretariat of Education of São Luís-MA, and schools themselves were used for the draw. The sample size at each school was proportional to the number of students in the school.

We used the Epi-Info software, version 6.0, to estimate the sample size. A sample of 180 adolescents would have a 95% power to detect significant prevalence ratios (PR) of 2.31[21], considering the prevalence of 19.8% of malocclusion among unexposed subjects[1], a 95% confidence level, and 1:1 ratio between unexposed and exposed subjects. We included an additional sample of 50% to supply possible losses, resulting in a sample of 270 adolescents. Besides, considering the effect of the complex sample design (*deff*) of 1.2[22,23], we added other 54 adolescents, reaching a minimal sample of 324 adolescents (162 unexposed and 162 exposed to at least one of the oral functional alterations investigated in this study).

The data collection period was March to September 2013. Inclusion criteria were 12 years of age and being enrolled in one of the elementary schools of São Luís. Students with syndromes, current or previous history of orthodontic-orthopedic treatment or myofunctional and articulatory therapy declared by parents or students, and those who have lost the first permanent molars were excluded.

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Team training

Evaluations were made by two collection teams. Each team had an interviewer/recorder and an examiner (orthodontist). The team was adequately trained for the application of the questionnaire and performance of clinical dental examinations. The diagnostic reproducibility (intra- and inter-examiner) was estimated by the Kappa test and the intraclass correlation test, accepting minimum values of 0.7. The intraclass repeatability ranged from 0.88 to 0.91 for clinical dental examinations and DAI. The inter-examiner repeatability for clinical dental examinations and DAI among the two examiners ranged from 0.79 to 0.81.

Pilot study

A pilot was performed considering all the variables involved in the study. The pilot study was carried out in a school with 32 adolescents to test the administration of questionnaires and clinical examination of schoolchildren, simulating real data collection situations. Those who participated in the pilot study were not included in the final sample. Adolescents participating in the pilot study received and answered the questionnaire, which was deemed appropriate, and no changes were necessary.

Clinical data collection

Clinical data were collected at school under a natural light source. Dental examinations were performed as per recommendations of the WHO[2]. An endodontic millimeter ruler, adapted silicone stop, and orthodontic wire were used for measurements[24] in the orthodontic examination.

Malocclusions were the outcomes of interest, which were evaluated through different criteria: Angle classification[25]; DAI[26]; and morphological changes not included in DAI – posterior open bite, posterior crossbite, and overbite[27].

Students were categorized as Class I, Class II (subdivision 1 and 2), and Class III[3] in Angle's classification. DAI was adopted to evaluate the presence and severity of malocclusion and the normative need for orthodontic treatment (NOT)[1,18]. It consists of 10 occlusal components divided into three dimensions: teething problems, occlusion, and space[26,27]. According to DAI, we classified student's malocclusion as normal/mild malocclusion (DAI≤25; no need for treatment); defined malocclusion (DAI=26-30, elective need); severe malocclusion (DAI=31-35, highly desirable need); or disabling malocclusion (DAI≥36, required need). Given that DAI does not mention morphological disorders such as crossbite, posterior open bite, and overbite[27], the evaluation of these items was included in the clinical examination.

Functional alterations of the stomatognathic system (breathing, phonation, chewing, and swallowing) were the main independent variables. The assessment followed the recommendations of some authors[13,18,28].

In the evaluation of the respiratory function, three criteria were observed. The first criterion concerned the lip seal without voluntary muscle contraction, whose presence is a sign of normality. The second criterion was related to the time in which the child could breathe with sealed lips, which was considered normal when the child could breathe this way for at least one minute. The third criterion consisted of placing a small mirror under the child's nostrils, who was requested to breathe normally. Mirror haze was considered a sign of normality. The presence of mouth breathing was characterized when at least one of these criteria was changed[18].

Adolescents with mandibular deviation, anterior or lateral tongue projection in the moment of articulation of phonemes or pronunciation of phonemes with sigmatism (vicious repetition of the "s" and other sibilants) were considered carriers of phonation problems[13].

About 20 g of bread was given to adolescents to identify chewing problems, evaluating the following criteria: labial sealing, accumulation of food in the oral vestibule, chewing side, and exaggerated participation of perioral muscles. Adolescents showing a change in one or more criteria were considered with chewing problem[29].

Swallowing was assessed by asking the child to put a small amount of mineral water (about 30ml) in the mouth and not swallow immediately. Then, using two wooden disposable spatulas to separate lips, the child was asked to swallow the water normally. This process was repeated twice. The swallowing pattern was considered atypical in the presence of lingual interposition between arches or when the tongue atypically pressed some front teeth[13].

Non-clinical data collection

The following covariates were also considered in the study: 1) sociodemographic data: gender (male or female); school type (public or private), economy class as per the Brazilian Association of Research Companies' (ABEP, acro-

nym in Portuguese) criteria (A/B, C or D/E) and self-reported skin color, according to Brazilian Institute of Geography and Statistics (IBGE, acronym in Portuguese) (white, black or other, including brown, yellow and red), school failure history (yes or no); 2) behavioral data: current or previous history of deleterious oral habits (pacifier/finger sucking, biting lips or cheeks, biting objects, nail-biting, gnashing teeth, sleeping with hands under the face or keeping hand under the chin and lingual interposition). The demographic and behavioral data were collected through a questionnaire.

Statistical analysis

The questionnaires were coded and revised in search of inconsistencies. Analyses were performed using Stata software, version 11.0 (Stata Corp., College Station, Texas, USA). Frequencies between groups were compared by Fisher's exact, chi-square, and chi-square (linear trend) tests. A significance level of 5% was adopted for rejecting null hypotheses in all analyses. Logistic and multinomial regression analyses with stepwise modeling strategy were performed, calculating the non-adjusted and adjusted odds ratio (OR). Covariates with P<0.2 in non-adjusted associations between malocclusion and covariates were considered potential confounders. Only covariates with P<0.10 in the adjusted analyses remained in the final model[30-32]. All analyses considered the design effect in estimating standard errors and were weighted by the inverse of the selection probability. We tested multicollinearity using the Stata command *_rmcoll*.

Ethical considerations

The study was approved by the Research Ethics Committee of the University Hospital of the Federal University of Maranhão. Written informed consent was obtained from the State Department of Education and school principals. The parents/guardians of the schoolchildren also signed a consent form after being informed about the research objectives, agreeing to the adolescents' participation in the research. We excluded students if their parents/guardians withdrew them from the study and if they declined to take part in the research.

Results

A total of 400 students, all aged 12 years old, were evaluated for their eligibility to participate in the study. We excluded 51 students: 17 were already receiving orthodontic treatment, and 34 had lost at least one first permanent molar. Of the 349 eligible students, 11 students refused to participate in the study and six students were not present in school at the second evaluation.

The sample consisted of eleven public and five private schools, totaling 332 students, with 82.7% public schools and 17.3% private schools. Most schoolchildren were male (53.1%), brown (65.2%), economy class C (59.7%), and had no history of school failure (66.5%).

Tables 1 and 2 show the malocclusions frequency distribution and study covariates, as per the occurrence of functional alterations. Differences were found in the malocclusion distribution, according to DAI (p=0.002), among those who had or not breathing alterations. A difference was found in the distribution of malocclusion, as per DAI (p=0.048) and Angle (p=0.003), by type of phonation problems (Table 1). Table 2 showed that the prevalence of MO according to Angle and posterior crossbite varied among patients with chewing alterations (p=0.012 and p=0.031) as well as among these with swallowing disorders (p=0.027 and p<0.001).

In the univariate regression analysis, as per DAI, adolescents with breathing alterations were more likely to have defined and disabling malocclusions. There was a collinear relationship between the type of school and economic class, so the first one was excluded from the adjusted analysis. After adjusting for confounders, it was found that the likelihood of having defined (OR=3.84; 95%CI=1.45-10.12) and disabling malocclusions (OR=4.34; 95%CI=1.99-9.49) and Class III malocclusion (OR=4.15; 95%CI=1.19-14.59) was higher among patients with breathing problems, compared to those with normal breathing (Table 3).

Association between phonation and disabling (DAI) and Class II malocclusion (Angle) was observed (Table 3). After adjustment of models, the likelihood of having defined malocclusion (OR=2.01; 95%CI=1.02-4.39), disabling malocclusion (OR=3.04; 95%CI=1.55-5.96) and Class II malocclusion of Angle (OR=2.02; 95%CI=1.28-3.18) was higher among patients with phonation problems when compared to those with normal phonation. The strength of associations was higher in disabling malocclusion. Although severe malocclusion was associated neither with breathing nor phonation alterations, the trend chi-square test was significant (Table 1).

There was an association between chewing disorders and posterior crossbite in both

Table 1. Malocclusions and sociodemographic and behavioral characteristics of the sample, according to breathing and phonation alterations. São Luís, Brazil.

Variables	Breathing alterations				P-value	Phonation alterations				P-value
	No		Yes			No		Yes		
	n	%	n	%		n	%	n	%	
Malocclusion (DAI)					0.002[1]					0.048[1]
Normal/Mild	81	84.1	16	15.9	0.007[2]	69	70.0	28	30.0	0.029[2]
Defined	51	55.1	31	44.9		47	51.9	35	48.1	
Severe	60	77.5	19	22.5		51	61.8	28	38.2	
Disabling	43	54.2	31	45.8		34	43.5	40	56.5	
Malocclusion (Angle)					0.494[3]					0.003[3]
Normal	10	85.3	2	14.7		11	96.5	1	3.5	
Class I	142	70.1	56	29.9		130	63.3	98	36.7	
Class II	72	72.5	31	27.5		51	53.1	52	46.9	
Class III	11	41.7	8	58.3		9	30.5	10	69.5	
Posterior crossbite					0.085[1]					0.280[1]
No	201	73.1	76	26.9		170	60.8	107	39.2	
Yes	34	53.4	21	46.6		31	47.9	24	52.1	
Posterior open bite					0.384[1]					0.298[1]
No	214	70.2	83	29.8		184	59.8	113	40.2	
Yes	21	65.0	14	35.0		17	48.0	18	52.0	
Overbite					0.165[1]					0.927[1]
No	142	72.9	51	27.1		118	58.7	75	41.3	
Yes	93	63.7	46	36.3		83	58.2	56	41.8	
Sex					0.724[1]					0.147[1]
Female	109	68.2	45	31.8		92	52.3	62	47.7	
Male	126	70.9	52	29.1		109	64.0	69	36.0	
Race/color					0.166[1]					0.082[1]
White	65	79.5	16	20.5		49	54.5	32	45.5	
Brown	147	66.6	70	33.4		126	57.1	91	42.9	
Black	23	67.7	11	32.3		26	73.8	8	26.2	
Economic class (ABEP)					0.224[1]					0.587[1]
A-B	102	74.9	35	25.1	0.132[2]	89	62.8	48	37.2	0.261[2]
C	117	68.2	51	31.8		95	55.8	73	44.2	
D-E	16	60.9	11	39.1		17	61.7	10	38.3	
School type					0.216[1]					0.134[1]
Public	162	68.5	74	31.5		137	56.7	629	43.3	
Private	73	75.1	23	24.9		64	67.3	185	32.7	

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unadjusted (OR=2.30; 95%CI=1.08-4.90) and adjusted (OR=2.32; 95%CI=1.12-4.82) models (Table 4). Adolescents with swallowing disorders were 466% more likely to have Class III malocclusion (OR=5.66; 95%CI=1.35-23.71), 513% more likely to have posterior crossbite (OR=6.13; 95%CI=2.76-13.62), and 353% more likely to have posterior open bite (OR=4.53; 95%CI=1.72-8.92) compared to those with normal swallowing (Table 4).

Discussion

This study suggests that malocclusion is not only an aesthetic problem but is probably associated with functional problems. Associations between breathing, phonation, chewing, and swallowing problems with malocclusion have been found, showing that the strength of association increases with increasing malocclusion severity, corroborating findings from other studies[13,18].

Table 1. Malocclusions and sociodemographic and behavioral characteristics of the sample, according to breathing and phonation alterations. São Luís, Brazil.

Variables	Breathing alterations				P-value	Phonation alterations				P-value
	No		Yes			No		Yes		
	n	%	n	%		n	%	n	%	
History of school failure					0.913[1]					0.752[1]
No	165	69.3	67	30.7		144	59.5	88	40.5	
Yes	70	70.3	30	29.7		57	56.6	43	43.4	
Pacifier sucking					0.986[1]					0.351[1]
No	160	69.6	62	30.4		134	56.1	88	43.9	
Yes	75	69.7	35	30.3		67	63.3	43	36.7	
Finger sucking					0.398[1]					0.764[1]
No	210	68.5	87	31.5		181	58.0	116	42.0	
Yes	25	77.4	10	22.6		20	61.7	15	38.3	
Biting lips/cheeks					0.476[1]					0.425[1]
No	125	71.7	51	28.3		108	60.7	68	39.3	
Yes	110	67.3	46	32.7		93	56.1	63	43.9	
Biting objects					0.077[1]					0.510[1]
No	154	73.8	52	26.2		123	57.1	83	42.9	
Yes	81	64.7	45	35.3		78	60.1	48	39.9	
Nail biting					0.978[1]					0.380[1]
No	86	69.8	36	30.2		75	62.2	47	37.8	
Yes	149	69.6	61	30.4		126	56.3	84	43.7	
Bruxism					0.094[1]					0.121[1]
No	193	72.9	74	27.1		165	61.6	102	38.4	
Yes	42	55.8	23	44.2		36	45.2	29	54.8	
Sleeping with hands under the face					0.252[1]					0.596[1]
No	157	72.1	58	27.9		130	59.5	85	40.5	
Yes	78	64.9	39	35.1		71	56.6	46	43.4	
Lingual interposition					0.913[1]					0.249[1]
No	201	69.9	86	30.1		174	60.7	113	39.3	
Yes	34	68.2	11	21.8		27	46.7	18	53.3	

[1]Chi-square test; [2]Trend chi-square test; [3]Fisher's exact test. Statistically significant P-values: P<0.05. DAI: Dental Aesthetic Index. ABEP: Economic class according to the Brazilian Association of Research Companies (Associação Brasileira de Empresas de Pesquisa - ABEP).

Source: Elaborated by the authors.

Breathing and phonation were associated with malocclusion in anterior segments of mouth arches, measured by indicators such as DAI, which is aimed at the aesthetic evaluation of the anterior region[4]. The proper respiratory function (nasal breathing) requires labial sealing, and tongue must be in contact with the palate, allowing proper growth and craniofacial development[18]. However, any respiratory disorder prevents labial sealing, and the tongue rests on the mouth floor, changing the palate shape, allowing the pressure of buccinator muscles to contribute to maxillary atresia and, therefore, to the onset of cross-sectional occlusal alterations[18].

In the adjusted analysis for confounders, it was found that the likelihood of having defined, disabling, and Class III malocclusion was higher among patients with breathing problems, compared to those with normal breathing. This association may be due to the genetic pattern of the individual, and not by presenting Class III malocclusion since it shows a significant genetic causal factor. This relationship is still a controversial subject. While some authors[11,33,34] found no significant association between mouth breathing and malocclusion and reported that the breathing mode does not influence craniofacial development, other studies[10,35] established a

Table 2. Malocclusions and sociodemographic and behavioral characteristics of the sample according to chewing and swallowing alterations. São Luís, Brazil.

Variables	Chewing alterations				P-value	Swallowing alterations				P-value
	No		Yes			No		Yes		
	n	%	n	%		n	%	n	%	
Malocclusion (DAI)					0.554[1]					0.453[1]
Normal/Mild	30	31.9	67	68.1	0.523[2]	74	80.0	23	20.0	0.160[2]
Defined	16	21.6	66	78.4		64	68.7	18	31.3	
Severe	20	29.2	59	70.8		57	73.6	22	26.3	
Disabling	19	27.2	55	72.8		50	67.7	24	32.3	
Malocclusion (Angle)					0.012[3]					0.027[3]
Normal	6	64.9	6	35.1		12	100.0	0	0.0	
Class I	41	20.3	157	79.7		145	73.1	53	26.9	
Class II	35	37.4	68	62.6		78	77.6	25	22.4	
Class III	3	11.9	16	88.1		10	36.8	9	63.2	
Posterior crossbite					0.031[1]					<0.001[1]
No	74	30.7	203	69.3		220	80.5	57	19.5	
Yes	11	14.6	44	85.4		25	40.3	30	59.7	
Posterior open bite					0.225[1]					0.114[1]
No	75	27.0	222	73.0		228	75.6	69	24.4	
Yes	10	35.0	25	65.0		17	54.8	18	45.2	
Overbite					0.078[1]					0.420[1]
No	55	33.1	138	66.9		147	75.5	46	24.5	
Yes	30	18.2	109	81.8		98	69.3	41	30.7	
Sex					0.352[1]					0.712[1]
Female	42	30.2	112	69.8		117	74.9	37	25.1	
Male	43	25.8	135	74.2		128	72.0	50	28.0	
Race/color					0.274[1]					0.190[1]
White	25	32.8	56	67.2		65	78.0	16	20.0	
Brown	50	23.8	167	76.2		153	69.8	64	30.2	
Black	10	40.3	24	59.7		27	80.2	7	19.8	
Economic class (ABEP)					0.870[1]					0.231[2]
A-B	40	29.6	97	70.4	0.218[2]	104	79.6	33	20.4	0.836[2]
C	39	27.2	129	72.8		118	68.1	50	31.9	
D-E	6	25.9	21	74.1		23	86.8	4	13.2	
School type					0.758[1]					0.610[1]
Public	56	27.2	710	72.8		174	72.8	62	27.2	
Private	29	31.0	220	69.0		71	76.0	25	24.0	
History of school failure					0.743[1]					0.825[1]
No	61	27.1	171	72.9		171	74.1	61	25.9	
Yes	24	29.2	76	70.8		74	71.9	26	28.1	
Pacifier sucking					0.612[1]					0.816[1]
No	54	26.9	168	73.1		163	72.8	59	27.2	
Yes	31	29.8	79	70.2		82	74.5	28	25.5	
Finger sucking					0.107[1]					0.188[1]
No	70	25.8	227	74.2		218	71.8	79	28.2	
Yes	15	41.2	20	58.8		27	83.9	8	16.1	
Biting lips/cheeks					0.104[1]					0.821[1]
No	48	31.6	128	68.4		125	72.8	51	27.2	
Yes	37	23.7	119	76.3		120	74.0	36	26.0	
Biting objects					0.251[1]					0.240[1]
No	48	25.9	158	74.1		155	76.2	51	23.8	
Yes	37	30.1	89	69.9		90	70.0	36	30.0	

it continues

Table 2. Malocclusions and sociodemographic and behavioral characteristics of the sample according to chewing and swallowing alterations. São Luís, Brazil.

Variables	Chewing alterations				P-value	Swallowing alterations				P-value
	No		Yes			No		Yes		
	n	%	n	%		n	%	n	%	
Nail biting					0.153[1]					0.789[1]
No	36	32.5	86	67.5		90	74.6	55	25.4	
Yes	49	25.1	161	74.9		155	72.6	87	27.4	
Bruxism					0.022[1]					0.284[1]
No	75	31.0	192	69.0		199	75.7	68	24.3	
Yes	10	14.2	55	85.8		46	63.1	19	36.9	
Sleeping with hands under the face					0.442[1]					0.226[1]
No	59	29.0	156	71.0		153	70.7	62	29.3	
Yes	26	25.5	91	74.5		92	78.4	25	21.6	
Lingual interposition					0.323[1]					0.699[1]
No	70	25.7	217	74.3		210	74.3	77	25.7	
Yes	15	39.2	30	60.2		35	68.4	10	31.6	

[1]Chi-square test; [2]Trend chi-square test; [3]Fisher's exact test. Statistically significant P-values:P<0.05. DAI: Dental Aesthetic Index. ABEP: Economic class according to the Brazilian Association of Research Companies (Associação Brasileira de Empresas de Pesquisa - ABEP).

Source: Elaborated by the authors.

Table 3. Unadjusted and adjusted association between breathing and phonation alterations and malocclusions. São Luís, Brazil.

Variables	Breathing alterations						Phonation alterations					
	Unadjusted analysis			Adjusted analysis			Unadjusted analysis			Adjusted analysis		
	OR	95%CI	P-value	OR	95%CI	P-value	OR	95%CI	P-value	OR	95%CI	P-value
Malocclusion (DAI)												
Normal/Mild	1	-	-	1	-	-	1	-	-	1	-	-
Defined	4.31	1.44-12.92	0.012	3.84[1]	1.45-10.12	0.010	2.17	0.83-5.67	0.107	2.01[1]	1.02-4.39	0.047
Severe	1.53	0.69-3.41	0.273	1.44[1]	0.69-3.01	0.303	1.44	0.65-3.21	0.341	1.43[1]	0.62-3.28	0.372
Disabling	4.47	2.17-9.18	<0.001	4.34[1]	1.99-9.49	0.001	3.03	1.56-5.91	0.003	3.04[1]	1.55-5.96	0.003
Malocclusion according to Angle												
Normal/Class I	1	-	-	1	-	-	1	-	-	1	-	-
Class II	0.94	0.60-1.46	0.763	0.87[2]	0.56-1.36	0.528	1.69	1.01-2.85	0.049	2.02[2]	1.28-3.18	0.005
Class III	3.45	0.67-17.72	0.127	4.15[2]	1.19-14.54	0.028	4.34	0.94-20.07	0.059	3.07[2]	0.95-9.92	0.059
Posterior crossbite												
No	1	-	-	1	-	-	1	-	-	1	-	-
Yes	2.38	0.86-6.60	0.090	2.36[3]	0.87-6.39	0.085	1.23	0.62-4.57	0.283	1.68[3]	0.62-4.57	0.283
Posterior open bite												
No	1	-	-	1	-	-	1	-	-	1	-	-
Yes	1.26	0.72-2.22	0.385	1.28[4]	0.70-2.31	0.396	1.61	0.62-4.17	0.302	1.59[4]	0.61-4.16	0.319
Overbite												
No	1	-	-	1	-	-	1	-	-	1	-	-
Yes	1.53	0.82-2.85	0.166	1.64[5]	0.81-3.34	0.157	1.02	0.65-1.59	0.927	1.05[5]	0.66-1.68	0.821

DAI: Dental Aesthetic Index. OR: Odds Ratio. 95%CI: 95% Confidence Interval. [1]Odds ratio adjusted for school failure, bruxism and finger sucking habit; [2]Odds ratio adjusted for sex, economic class, biting objects, finger sucking and lingual interposition; [3]Odds ratio adjusted for economic class and habit of biting objects; [4]Odds ratio adjusted for school failure; [5]Odds ratio adjusted for school failure and economic class.

Source: Elaborated by the authors.

Table 4. Unadjusted and adjusted association between chewing and swallowing alterations and malocclusions. São Luís, Brazil.

Variables	Chewing alterations						Swallowing alterations					
	Unadjusted analysis			Adjusted analysis			Unadjusted analysis			Adjusted analysis		
	OR	95%CI	P-value	OR	95%CI	p-value	OR	95%CI	P-value	OR	95%CI	P-value
Malocclusion (DAI)												
Normal/Mild	1	-	-	1	-	-	1	-	-	1	-	-
Defined	1.45	0.75-2.81	0.247	1.39[1]	0.64-2.74	0.415	0.90	0.45-1.82	0.780	1.57[1]	0.61-4.06	0.322
Severe	1.16	0.46-2.92	0.731	1.09[1]	0.43-2.74	0.851	1.24	0.63-2.45	0.532	1.38[1]	0.71-2.69	0.322
Disabling	1.38	0.49-3.87	0.511	1.28[1]	0.51-3.21	0.579	1.54	0.79-3.03	0.207	1.94[1]	0.90-4.17	0.087
Malocclusion according to Angle												
Normal/Class I	1	-	-	1	-	-	1	-	-	1	-	-
Class II	0.77	0.31-1.96	0.574	0.73[2]	0.30-1.77	0.463	0.86	0.37-2.00	0.715	0.80[2]	0.33-1.96	0.612
Class III	3.39	0.88-13.03	0.072	3.66[2]	0.88-15.23	0.072	5.13	1.11-18.78	0.046	5.66[2]	1.35-23.71	0.021
Posterior crossbite												
No	1	-	-	1	-	-	1	-	-	1	-	-
Yes	2.30	1.08-4.90	0.032	2.32[3]	1.12-4.82	0.027	6.12	2.68-13.97	<0.001	6.13[3]	2.76-13.62	<0.001
Posterior open bite												
No	1	-	-	1	-	-	1	-	-	1	-	-
Yes	0.60	0.24-1.49	0.250	0.60[4]	0.24-1.51	0.261	3.55	0.75-8.65	0.124	4.53[4]	1.72-8.92	0.037
Overbite												
No	1	-	-	1	-	-	1	-	-	1	-	-
Yes	1.64	0.66-4.07	0.265	1.79[5]	0.78-4.10	0.157	1.36	0.61-3.04	0.421	1.42[5]	0.59-3.42	0.404

DAI: Dental Aesthetic Index. OR: Odds Ratio. 95%CI: 95% Confidence Interval. [1]Odds ratio adjusted for school failure, bruxism and finger sucking habit; [2]Odds ratio adjusted for sex, economic class, biting objects, finger sucking and lingual interposition; [3]Odds ratio adjusted for economic class and habit of biting objects; [4]Odds ratio adjusted for school failure; [5]Odds ratio adjusted for school failure and economic class.

Source: Elaborated by the authors.

direct relationship between mouth breathing and malocclusion.

In this research, the likelihood of having defined, disabling, and Class II malocclusion was higher among patients with phonation problems when compared to those with normal phonation. The strength of associations increased with increasing malocclusion severity. This result corroborates other studies[13,36] that also found an association between phonation disorders and abnormal occlusion, including changes in the anterior segment of the mouth, such as anterior open bite.

Another research[12] showed that Class III malocclusion, diastema, open bite, deep bite, and increased overjet tend to be associated with speech disorders, as these occlusal disorders modify phonemes. The most commonly found in literature regarding the relationship between speech with malocclusion as per Angle is the presence of lisping in individuals with Class II malocclusion, because the tongue tends to be positioned with high back and with its lower end in the oral cavity, favoring the change of the articulation point of fricative phonemes /s/ and /z/[14].

The chewing and swallowing functions were associated with occlusal imbalances in the posterior region. Chewing disorders were associated with a higher prevalence of posterior crossbite among the adolescents included in our study. This association may due to posterior crossbites can produce a lack of contact in some teeth, thus, in spite of presenting all teeth, subjects with malocclusions may have less occlusal pairs, which can impair their mastication[37,38].

Adolescents with swallowing disorders had a higher prevalence of Class III malocclusion, posterior crossbite, and posterior open bite when compared to those with normal swallowing. Another investigation[39] found that tongue positioned in the genius region can determine mandibular prognathism, leading to Class III malocclusion. They also reported that if the tongue is positioned more forward and down, pressing the anterior teeth during swallowing leads to excessive pressure of the perioral muscles on flex-

ible bone structure, resulting in a narrowing of the maxillary arch, supra-eruption of posterior teeth, buccoversion of anterior teeth, crossbite and open bite.

The results of the association between swallowing and malocclusion in this investigation also corroborate the study by Suliano et al.[13], who found decreased normality of this function with increasing malocclusion severity. Atypical swallowing might lead to changes in the craniofacial pattern and mandibular morphology[16].

A study[29] with adolescents aged 12-15 years concluded that atypical swallowing had a significant impact on malocclusion, resulting in a higher frequency of crowding in anterior teeth, open bite, and spacing. Another research[40] reported the importance of taking into consideration factors such as time, intensity, and frequency of habit to relate atypical swallowing as an etiological factor of malocclusion, which is challenging to evaluate in epidemiological studies. Marcomini et al.[15] found an association between swallowing and malocclusion, specifically with open bite, but not with a posterior crossbite.

It is essential to know whether the "impulse" of the tongue during swallowing and other functional behavior is responsible, if it contributes to, or is a consequence of the development of malocclusion[17]. The data obtained in this study do not allow establishing causal relationships. The cross-sectional design of this study does not allow saying whether the change in the function causes malocclusion or vice versa.

Some hypotheses are raised to explain such differences. Some authors studied malocclusion in the primary dentition in children aged 3-5 years[29], others in mixed dentition[12], and others included adolescents aged 12 years in permanent dentition stage[9]. Our sample included only adolescents aged 12 years, considered as age-index for overall monitoring of various oral health problems by WHO for international comparisons and monitoring of trends[1,2]. Most studies include large age groups, which hampers the comparison of results since they can have deciduous, mixed, and permanent dentition in a single study.

Differences in sampling design may also have influenced the results because few studies have adopted the same design (probability cluster and stratified sampling, simple random selection) of this work. This type of method results in estimation with a lower probability of selection bias. Also, the use of multivariate analysis reduces the likelihood of confounding bias. An important aspect refers to the stomatognathic dysfunctions' diagnostic criteria. The tests considered different clinical aspects, objectively evaluated by previously trained examiners, according to the previous recommendations[2,12,27,28], thus reducing the occurrence of measurement bias.

This study had some limitations, such as the time to complete the questionnaire and the fact that some students gave up participation during the examination, and some schools limit the time for the research so that students do not miss class. Nevertheless, *these limitations do not detract* from the usefulness of the *study.*

The strengths of this study are: i) the probabilistic sampling design ensured good representativeness of the study population, and results can be extrapolated for a similar population and also for an external validation; ii) narrow confidence intervals that show the accuracy of association estimates; iii) malocclusion evaluation methods using different criteria – students were evaluated by Angle classification, DAI and other changes not included in DAI (posterior open bite, posterior crossbite, and overbite); iv) to the best of our knowledge, there are no previous studies considering these four oral functions alterations (breathing, phonations, chewing and swallowing); v) multivariate analyses contribute to the reduction of possible confounding biases; also, all analyzes considered *deff* and were weighted by the unequal selection probabilities of the subjects; vi) some strategies to reduce measurement bias were the use of examiners specialized in Orthodontics, that completed a training and a pilot study, with acceptable Kappa measurements.

However, it is necessary to develop longitudinal studies that follow people with malocclusion problems for a better understanding of the association with alterations of oral functions, as well as the dose-response relationship.

We emphasize the importance of this topic for public health because alterations in oral functions and severe malocclusions affect an important portion of the population, creating a demand for rehabilitation in different areas of health, especially Dentistry and Phonoaudiology.

Conclusions

Malocclusion is associated with functional alterations of the stomatognathic system. Breathing and phonation changes are associated with malocclusions in the anterior segments of the oral cavity, while chewing and swallowing are associated with malocclusions in the posterior segment

of the oral cavity. The strength of the association between functional alterations and malocclusions increases with increasing malocclusion's severity. Therefore, the analysis of oral functions should be part of clinical examination protocols in health services.

Collaborations

HV Freitas and EBAF Thomaz worked on the conception of the work. HV Freitas and LFG Silva worked on the acquisition of data for the work. EBAF Thomaz worked on analysis and interpretation of data for the work. CMC Alves, LFG Silva, ALP Pereira, FN Hugo and EBAF Thomaz worked on drafting the work or revising it critically for important intellectual content; and final approval of the version to be published.

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